Testing Snow Grain Size Retrieval Through Comparison With MODIS/CERES Radiances Over Antarctic Plateau

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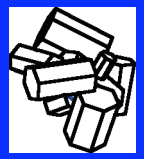
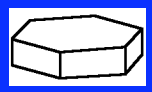
Brief Review of Previous Results

1. Calculated and compared the snow optical properties for different snow particle shapes:

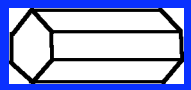
Sphere



Aggregate



Plate



Solid column

2. Made a series of sensitivity tests, and evaluated the snow optical properties through comparisons with in situ measurements of spectral albedo and radiance distribution at Dome C, Antarctic. The results showed:

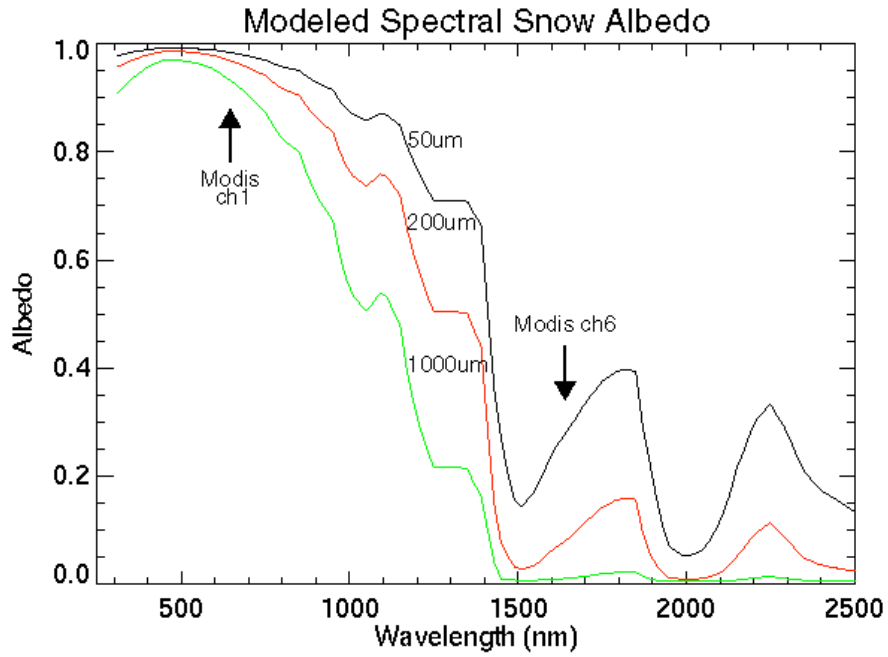
- **On average, the assumption of Aggregate particle shape has the best match with measurements.**
- **Snow grain size and its vertical profile are important for simulating spectral radiation, so that at least a two-layer snow model is required to match the observations.**
- **Snow grain size is retrievable, but some observation angles (e.g., large view zenith close to the principal plane) should be avoided.**

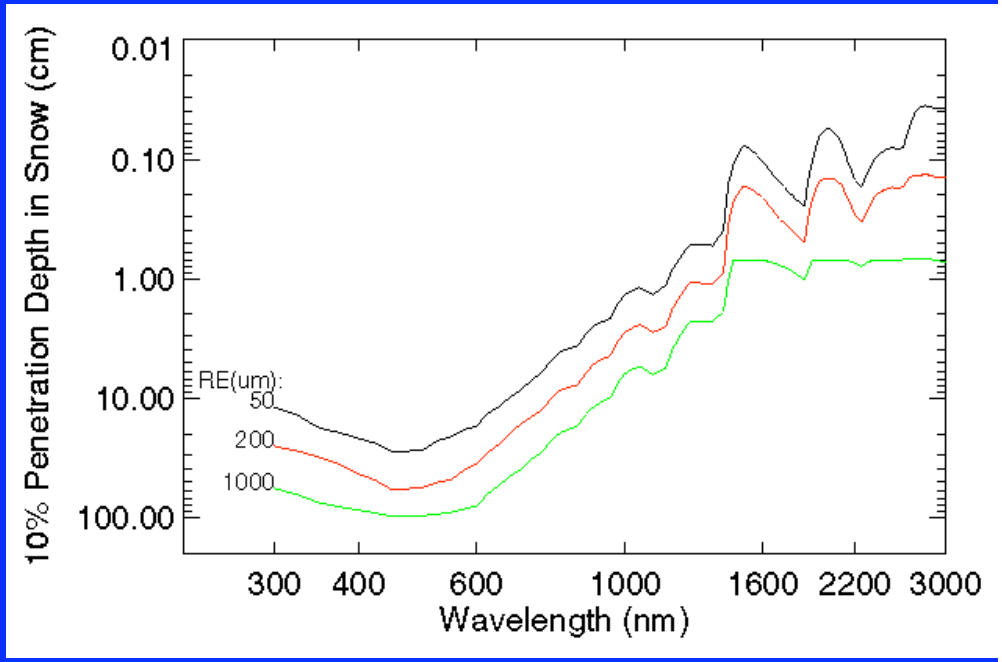
3. Made some preliminary comparison of radiances between model and satellite measurements (1 layer retrieved RE; SW image channels in CERES SSF only).

A recent update of the snow optical properties is the consideration of micro-scale particle surface roughness.

On average, the roughness effect is small and this effect is mainly on the scattering phase function. Increasing roughness tends to smooth the scattering phase function.

Two-layer Snow Grain Size Retrieval





A NIR channel is good for grain size retrieval.

A visible channel must be used for deeper layer of snow.

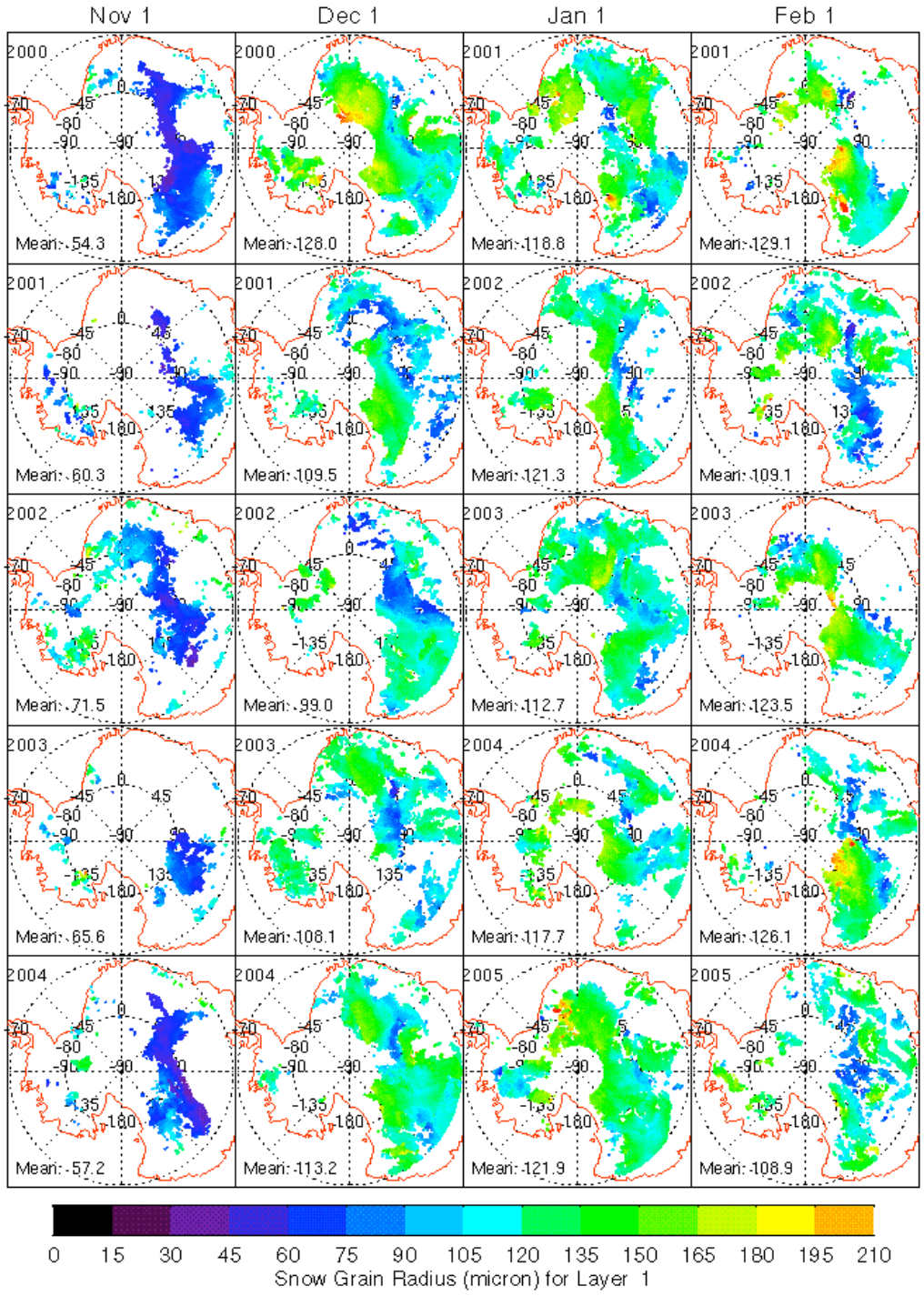
MODIS channel 6 (1.64μm) is selected for the first layer RE retrieval;

Channel 1 (0.645μm) for the second layer RE.

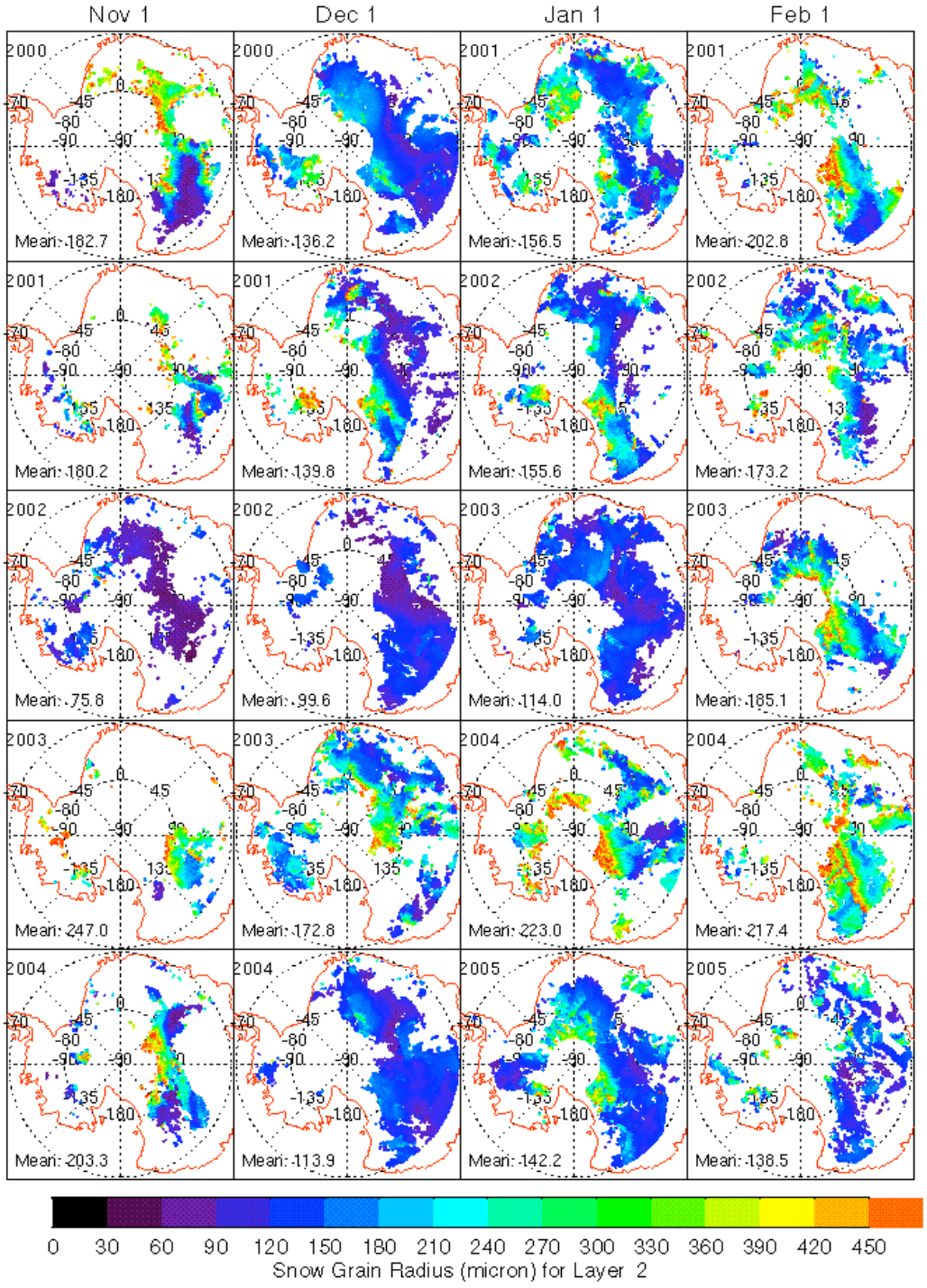
Two reflectance LUTs are created:

$$r_{164} = r(\theta_0, \theta, \phi, h_s, \tau_a) \longrightarrow RE_1$$

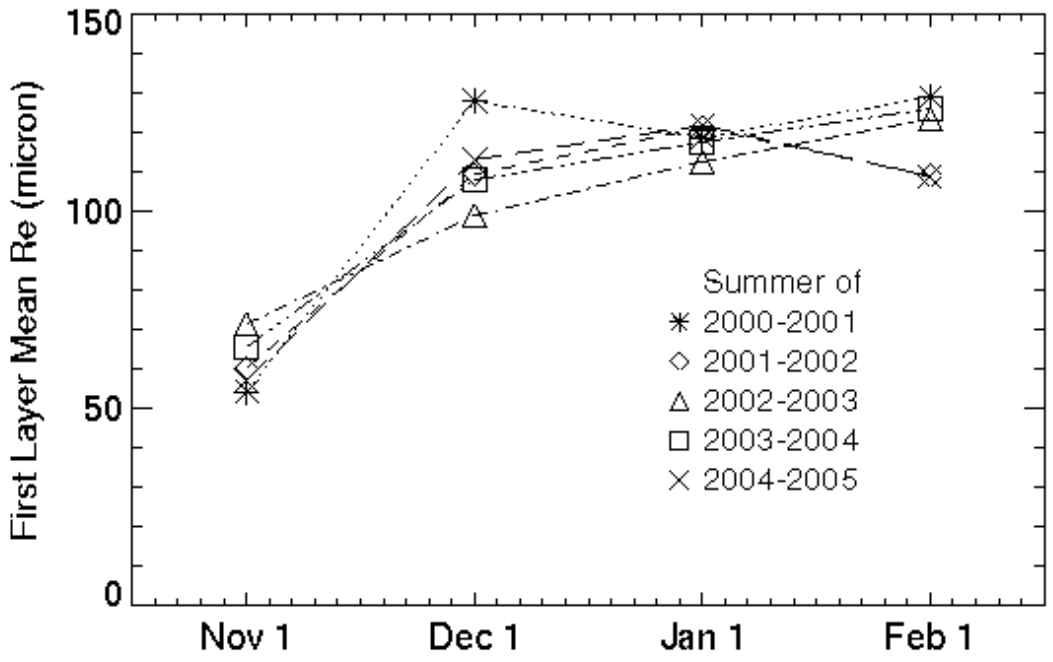
$$r_{064} = r(\theta_0, \theta, \phi, h_s, \tau_a, o_3, RE_1) \longrightarrow RE_2$$

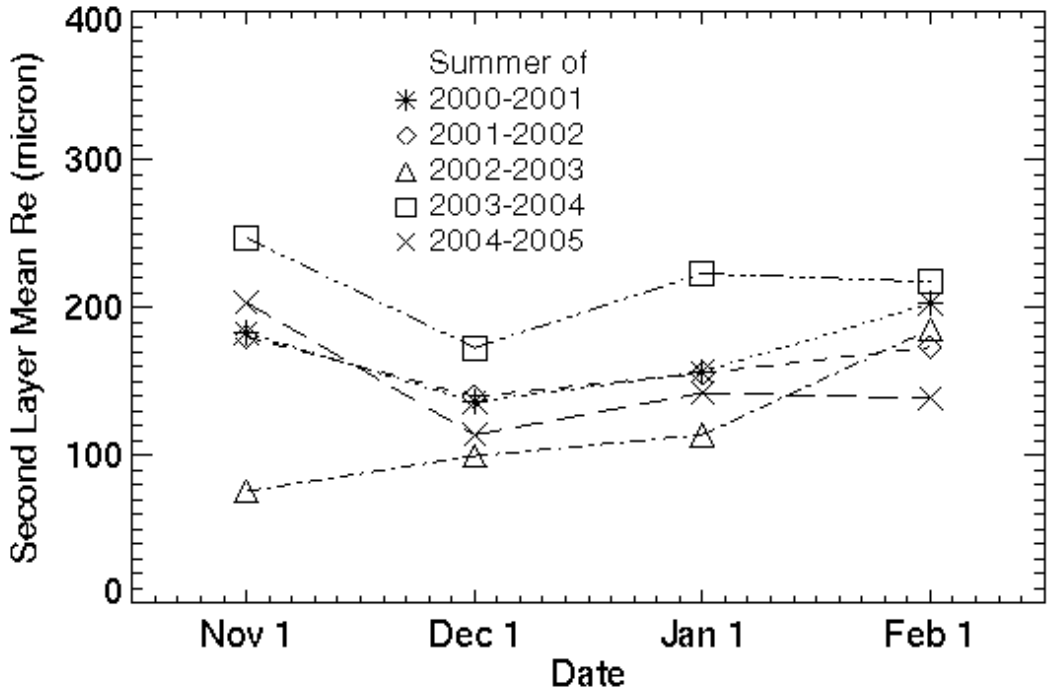


First layer snow grain size (*RE*) in the four days (four columns) in five years (five rows).



Second layer snow grain size (*RE*) in the four days (four columns) in five years (five rows).


First Layer Mean Re (micron)
150
100
50
0
Nov 1
Dec 1
Jan 1
Feb 1
Summer of
2000-2001
2001-2002
2002-2003
2003-2004
2004-2005


Second Layer Mean Re (micron)
400
300
200
100
0
Nov 1
Dec 1
Jan 1
Feb 1
Date
Summer of
2000-2001
2001-2002
2002-2003
2003-2004
2004-2005

Comparison of MODIS/CERES Radiances With Model Simulation

How good is the retrieved snow grain size (RE)???

Using the retrieved RE as input, can RT modeled radiances match satellite measurements?

To check the RE retrieval, the retrieved RE is used to simulate the MODIS/CERES radiances.

CERES SW and three MODIS channels (0.55μm, 0.86μm, and 2.13μm), which are independent of the two size retrieval channels, are selected for radiance calculations.

The three MODIS channels represent different sensitivities to the snow grain size :

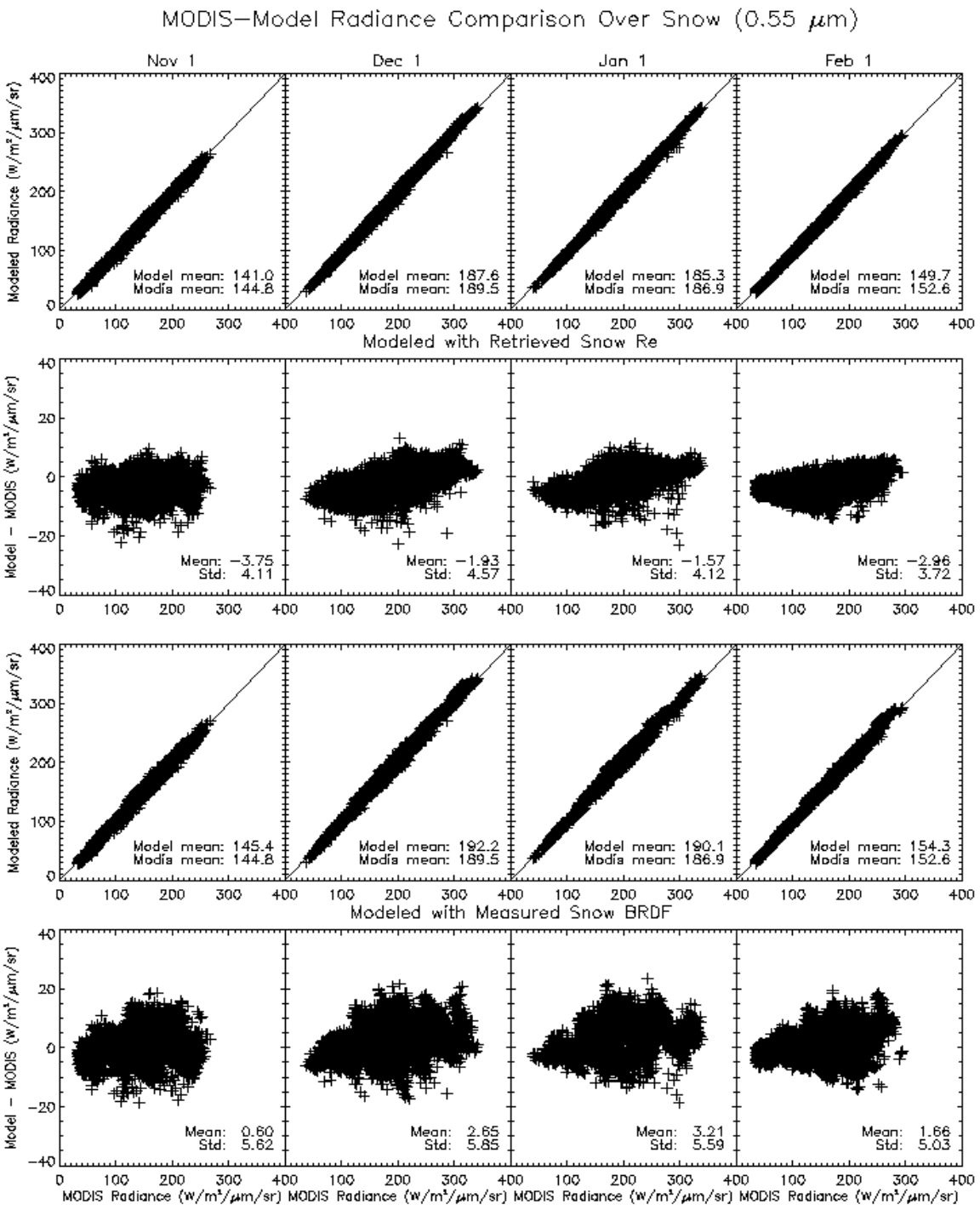
- **2.13μm: very sensitive**
- **0.86μm: moderate sensitive**
- **0.55μm: not sensitive**

How sensitive is the broadband SW to RE?

CERES/MODIS data selection criteria:

1) *Clear fraction = 100%*
2) *100% snow in each footprints*
3) *Relative STD of imager radiances < 3%*
4) *T_surface < 270°K for snow surface*
5) *Observations with view zenith > 30° in forward scattering plane are excluded.*

Data are from the same four days each summer from 2000 to 2005 as for the RE retrieval presented above.



Model-MODIS radiance (0.55μm) comparison. The four columns are for the four days and the five years of data for each date are combined together. The upper two rows show the modeled results using the retrieved *RE*; the lower two rows show modeled results using the measured surface reflectance at Dome C. Clear CERES footprints with surface level > 2500m.

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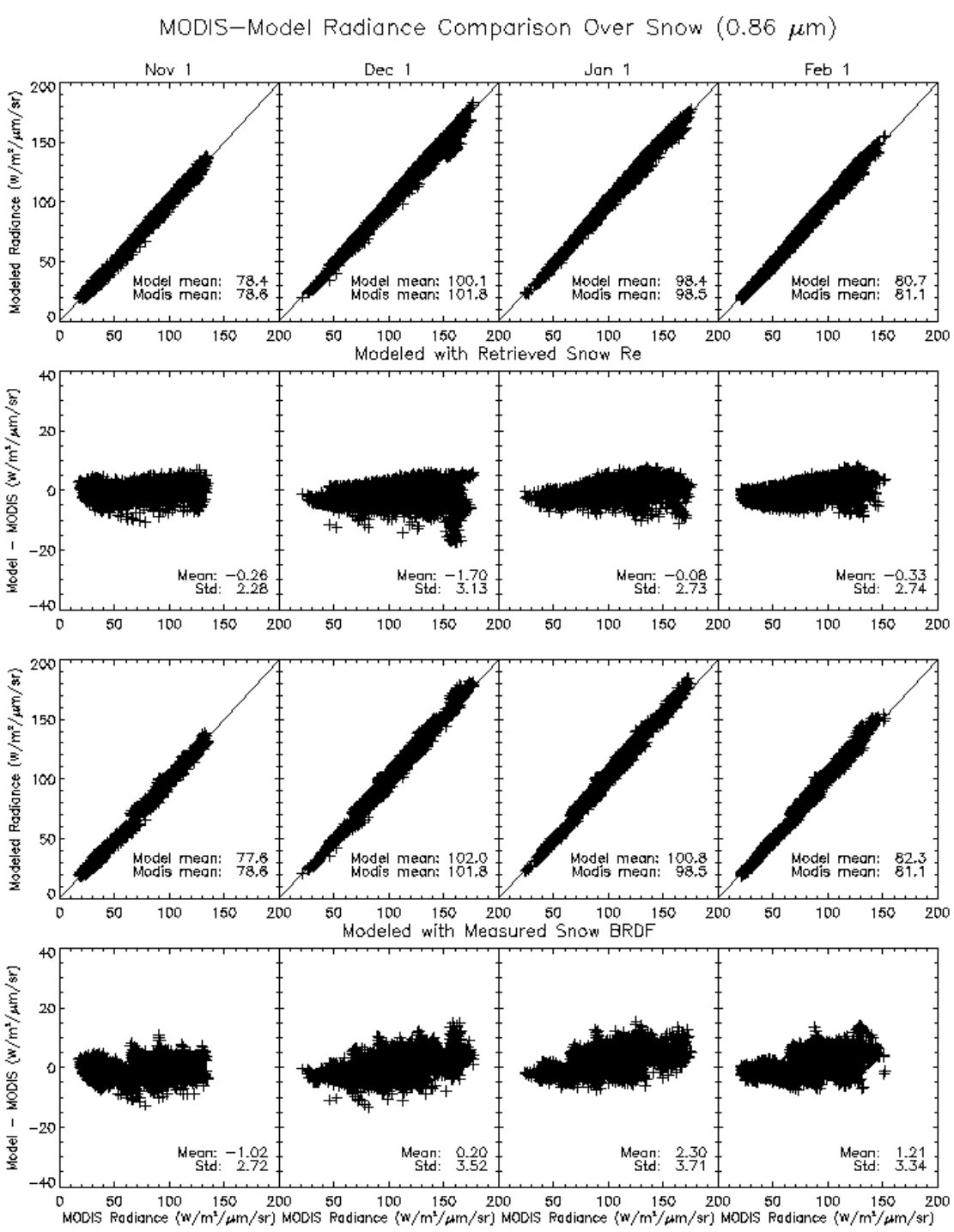
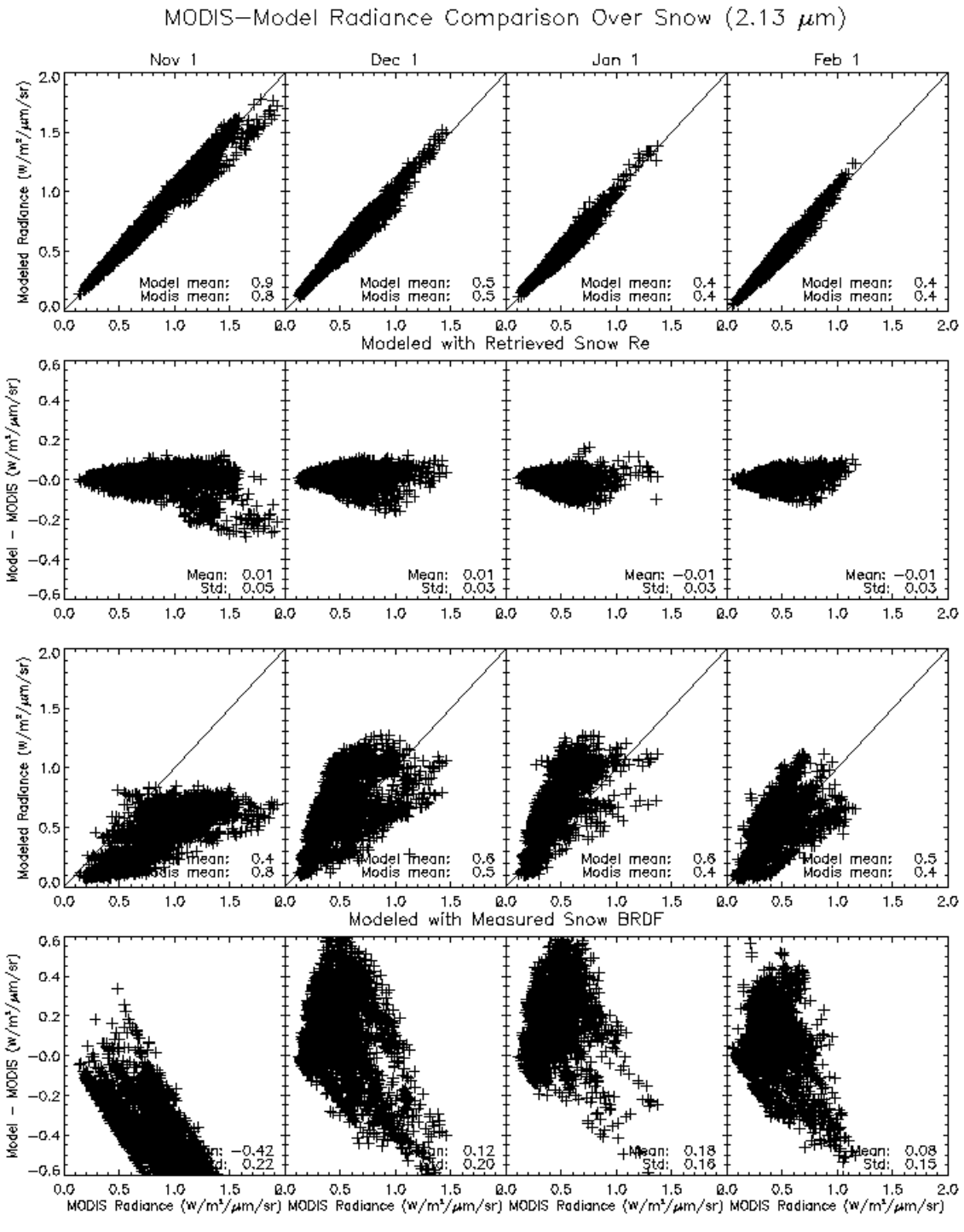
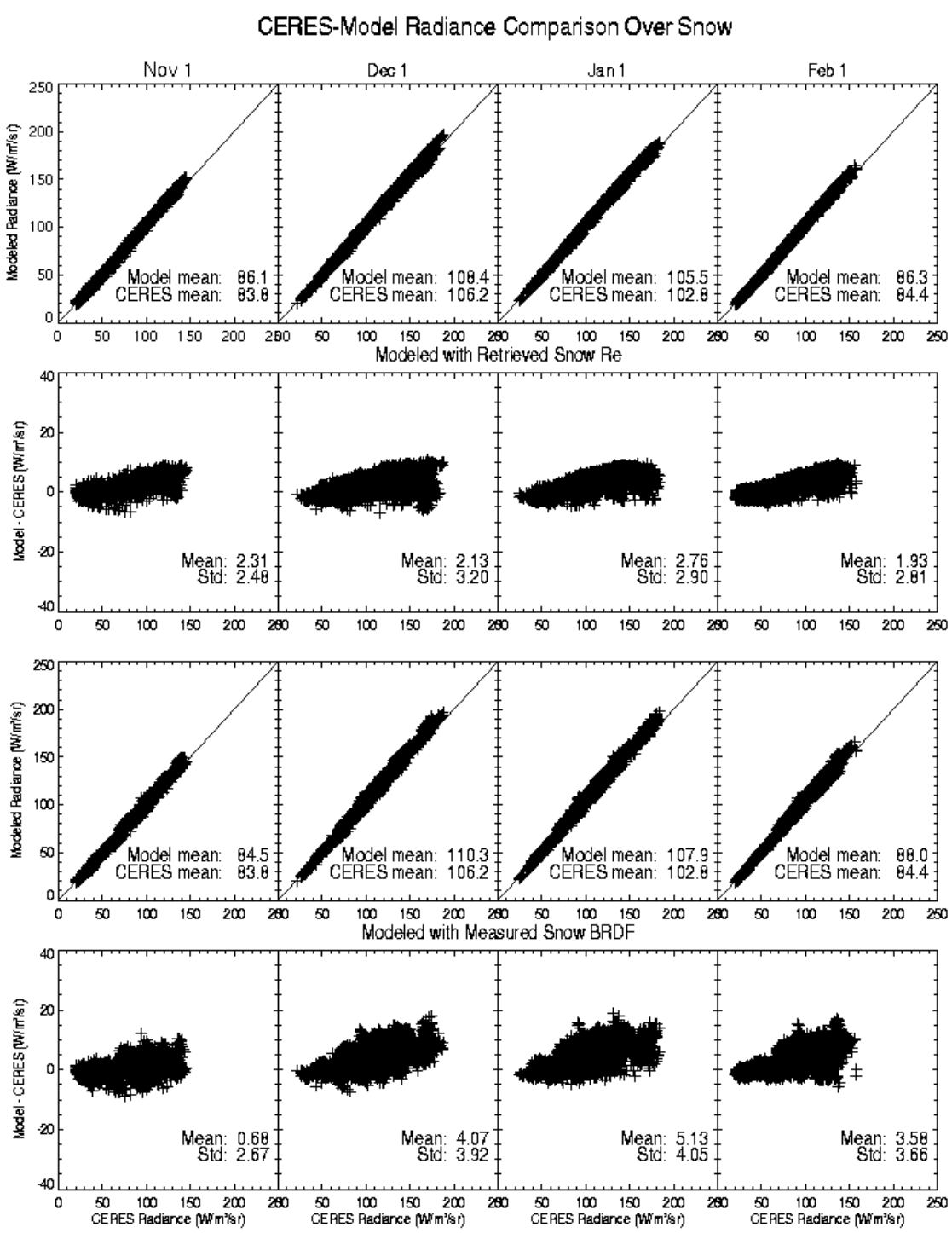
CERES
NASA



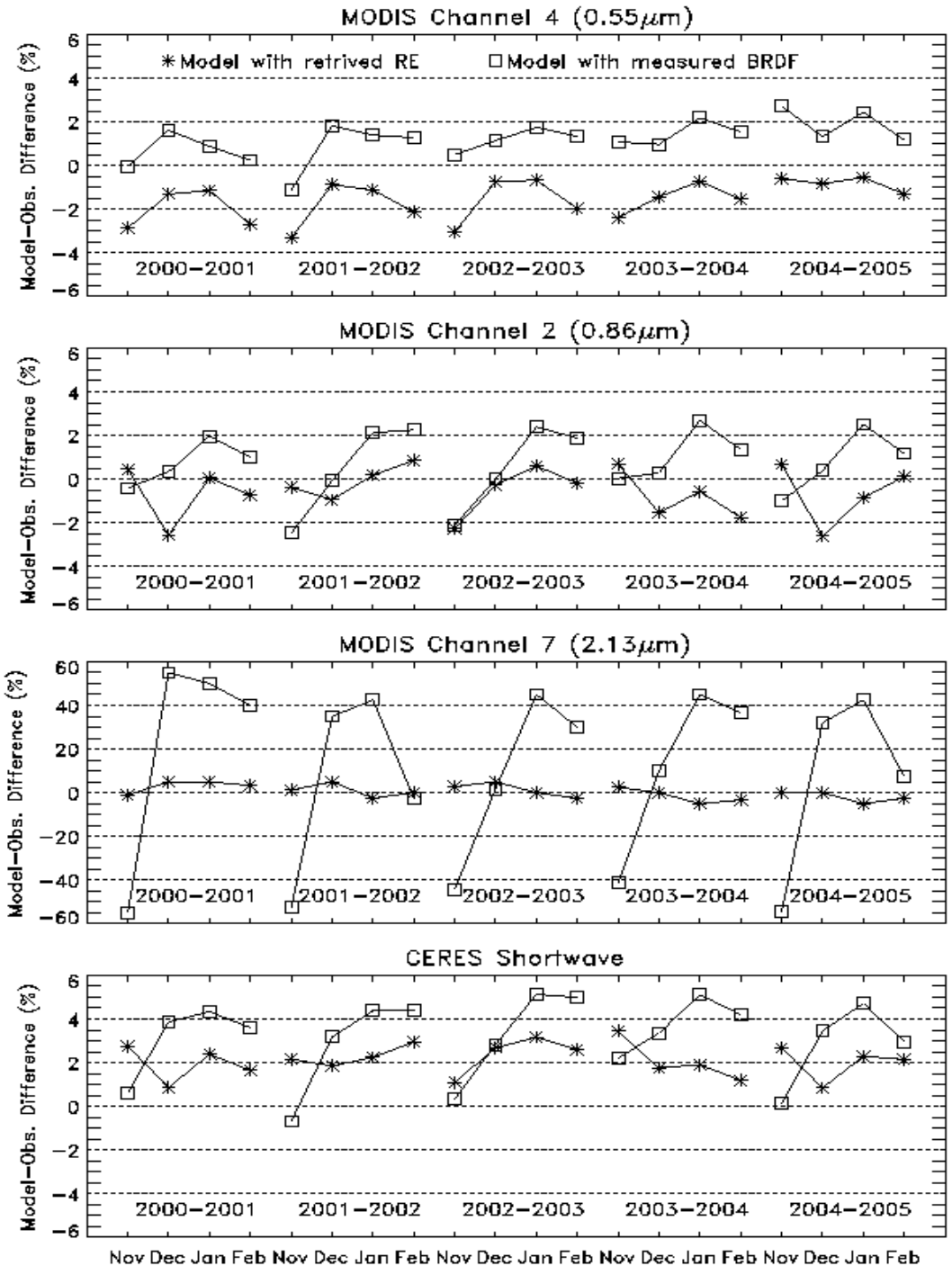
Same as the plot above, but for MODIS Channel 2 (0.86μm).



Same as the plot above, but for MODIS Channel 7 (2.13μm).



Same as the plot above, but for CERES shortwave.



The relative discrepancies for the modeled radiances in the three MODIS channels (the upper three panels) and the CERES shortwave (the lower panel). Data are from the four days in five years from 2000 to 2005

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Summary

- A two-layer snow RE retrieval algorithm is developed and applied to the Antarctic plateau.
- The retrieved top layer snow RE over Antarctic plateau shows similar and large seasonal variation in all years but shows small year-to-year variation. The deeper layer snow RE is larger and doesn't show similar variations as the top layer.
- The retrieved RE is used to model the spectral radiances in three representative MODIS channels and the CERES SW radiance. The good model-observation agreements indicate that the retrieved RE is accurate.

- An independent modelling approach, which directly uses the measured surface BRDF and hence is irrelevant to the snow properties, is also used to model the radiances.
- The consistence between the two independent modelling approaches indicates that the treatment of the snow optical properties in the coupled atmosphere-snow RT model is reasonable.
- The results also demonstrate the grain size effects on snow reflectance. The broadband SW radiance is moderately sensitive to the snow grain size, comparable to the MODIS 0.86μm channel.
- The broadband SW albedo over Antarctic plateau is not constant, but has an approximately 5% of variation in a year.

Acknowledgments:

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